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Impact of artificial light at night on the foraging behaviour of the European Hamster: consequences for the introduction of this species in suburban areas

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Abstract

Among the pressures introduced by urbanization, artificial light at night (ALAN) can be problematic, particularly for nocturnal species. Populations of European hamsters (*Cricetus cricetus*) have dramatically decreased in France since 1972 because of habitat loss due to urbanisation and changes in agricultural methods. The conservation project Life Alister aims to increase the abundance of this species in suburban areas via hamster release. However, the success of this population-restoration project may be compromised due to the possible effects of ALAN on the daily and seasonal cycles and behaviour of this nocturnal species. To understand how hamsters may respond to relocation, we experimentally studied the impact of ALAN on hamster foraging, a decisive behaviour for survival in natural habitats. This study assessed the behavioural responses of 18 animals when choosing between two food sources of different palatability in two different lighting conditions: artificial light (4 or 40 lux) or darkness. Our results show that hamsters avoided lighting that mimics suburban streetlights, particularly when grooming. Moreover, this study reveals that hamsters do not avoid street-lit areas when highly palatable food is present, suggesting they would be more susceptible to predation under these circumstances. Our results suggest that the adverse effects of ALAN on the behaviour of hamsters released on the outskirts of developed suburban areas could be limited by restricting the number of street lights, moderating the intensity of street lighting, or switching lights off during the hours hamsters are most active. We further recommend that wildlife managers avoid planting plants that are highly palatable to hamsters close to lighting in suburban areas to limit the risk of predation for this species.

Keywords
Conservation, Cricetus cricetus, Anthropization, street light

Introduction

Given the increase of the human population living in urban areas (Seto et al. 2010) that has been observed in the last 50 years, urbanisation has dramatically expanded, invading rural areas and exposing wildlife to new environmental pressures. The decrease observed in the Alsatian population of European hamsters (*Cricetus cricetus*) since 1972 is reported to be caused by habitat loss resulting from urbanisation and changes in agricultural practices, notably intensive cereal monoculture (O'Brien 2015; Tissier et al. 2016a and 2017). This species is listed on the 4th annex of the European Union Directive for habitat conservation as a highly threatened mammal species and the steady decline of the population in France has alerted authorities of the importance of protecting the almost extinct population, which is located in the Alsace region (Villemey et al. 2013). In addition to national conservation programs, the Life Alister project aims to develop the presence of this species in suburban areas (LIFE Biodiversity ALISTER (LIFE12 BIO/FR/000979)). Indeed, populations of hamsters have successfully habituated to anthropization in other regions of Europe, such as Austria (Franceschini and Millesi 2003), Russia and Ukraine (Feoktistova et al. 2013) and Slovakia (Čanády 2013) where cities have expanded into hamster habitats, a process called synurbanisation (Surov et al. 2016). However, artificial light at night (ALAN), inherent to urban areas, can be problematic for hamster survival after release. While ensuring the comfort and safety of humans through the night in urban areas, ALAN has negative effects on some organisms living in anthropic environments (Gaston et al. 2014, 2015a, 2015b; Navara and Nelson 2007). For instance, ALAN disrupts circannual cycles, such as reproduction seasonality (Goldman 2001; Dominoni et al. 2013; Robert et al. 2015; Le Tallec et al. 2016; Gaston et al. 2017), which can lead to decreased reproductive success (Ikeno et al. 2014; Cissé et al. 2017 but see Stracey et al. 2014 for increased reproductive success of birds). ALAN can also generate the appearance of a "night light niche" (Garber 1978; Russ et al. 2015; Silva et al. 2017), corresponding to the colonisation of the nocturnal niche by diurnal species and thus increasing interspecies competition and predation. Animals can also modify their foraging patterns in response to increased nocturnal visibility to reduce their risk of predation (reported in fishes: Clark and Levy 1988; Becker et al. 2013, and in rodents: Clarke 1983; Kotler et al. 1991; Bird et al. 2004; Farnworth et al. 2016). More precisely, in rodents, Farnworth et al. (2016) demonstrated an association between illuminated areas and predation risk in both captive and wild mice. In addition, Bowers (1988) reported that desert rodents show significantly more avoidance behaviour when an area of their habitat is illuminated during the full moon than during the new moon. As the successful hunting of prey appears to be facilitated by nocturnal illumination (Kaufman and Kaufman 1982; Lockard and Owings 1974; Price et al. 1984; Rosenzweig 1974, Miller et al. 2017), prey species have had to adapt their behaviour to avoid illuminated areas of their environment (Clarke 1983; Wolfe and Summerlin 1989; Lima 1998; Jacob et

al. 2017; Beier 2006), which they associate with a higher predation risk (Orrock et al. 2004; Navarro-Castilla et al. 2018; Lima and Dill 1990). Moreover, the avoidance of illuminated zones by rodents tends to reduce their foraging area and thus probably limits their available food resources (Bowers 1988; Kotler 1984a, 1984b; Price et al. 1984, Vijayan et al. 2018). Indeed, O'Dowd and Hay (1980) indicated that diversity in the diet composition of rodents seems to be negatively correlated with predation risk.

In this study, we aim to evaluate the possible use of suburban areas as relocation habitats for the protection of European hamsters in France. We focused on areas bordering developed zones (i.e. suburban areas), as these areas have lower levels of perturbation by humans and may thus provide favourable conditions for hamster conservation. However, anthropic disturbance may impact the introduction of hamsters in suburban areas, in particular due to the effects of ALAN. European hamsters are nocturnal and territorial, so ALAN could modify their daily and seasonal cycles and change their behaviour, ultimately impacting individual fitness. For these reasons, we question whether the release of hamsters in suburban areas will actually facilitate restoration of this threatened population. In this paper, to understand how hamsters may respond to relocation, we experimentally studied the impact of artificial lighting on the foraging behaviour of the hamster. With this experiment, we aimed to determine how hamsters bred in captive conditions react when faced with two sources of food (of high or low palatability) under different light intensities typically found in Alsatian cities (in terms of wavelength and light intensities). We hypothesised that the foraging pattern of hamsters will be modified when individuals are confronted with light in the environment and that hamsters will generally show an aversive response to ALAN.

Material and methods

Ethics statements

The experimental protocols followed EU Directive 2010/63/EU guidelines for animal experiments and the care and use of laboratory animals, and were approved by the Ethical Committee (CREMEAS) under agreement number APAFIS#3809-2016012713151858.

Animals

The 18 hamsters tested in this experiment were adults (2-year old) born and bred in the laboratory breeding centre of the Institut Pluridisciplinaire Hubert Curien in Strasbourg, France. A balanced sex ratio of nine males and nine females was studied. To align with the solitary behaviour of this species, all individuals were housed individually in cages (dimensions 38.5 × 121.5 × 18 cm), which were enriched with nesting materials (cellulose and hay). Animals were maintained at a constant ambient temperature of 18 °C and a relative humidity of 55%. Animals of this centre are bred to be released

in the wild for repopulation purposes and are reared under normal photoperiod conditions. Therefore, during the daytime photoperiod, fluorescent lamps emitting 944 lux at mid-height, were synchronised with the sunrise and sunset and with the natural progressive light intensities at this latitude. Kibbles (pellets 105; Safe, Augy, France, composed of 19.3% protein, 54.9% carbohydrates, 5.1% lipids, 4.2% cellulose, 5.0% minerals and 11.5% water) and water were available *ad libitum*. Hamsters were studied for 8 weeks after emerging from hibernation at the beginning of April 2016. Animals were manipulated using a box to move them from their cages to the experimental test arena in order to reduce stress and limit their contact with humans.

Foraging experiments

This experiment investigated whether ALAN modifies the foraging patterns of hamsters. To ensure that analogous suburban lighting conditions were successfully reproduced, a lux meter was used prior to testing to measure the light intensity a hamster would experience if 1) directly below the streetlight and 2) in the peripheral zone (at a distance of 15 m) of a streetlight in a suburban area. The distance between two street lamps in a Strasbourg periphery is an average of 35 m. The resulting intensities of 40 lux and 4 lux, respectively, were then reproduced in experimental conditions using light bulbs (Luxeon, type Rebel PC Amber-LXM2-PL010000, dominant wavelength 591.0 nm) that imitate the high-pressure sodium bulbs used in the current lighting system of Strasbourg, Alsace, France.

We built a test arena (dimensions 150 × 80 × 50 cm) composed of two compartments connected via a 10 cm x 10 cm opening, and placed it in a dark room (Figure 1A). An identical source of artificial light (an amber LED emitting at 0, 4 or 40 lux) was placed 80 cm above the floor of each compartment. One of the compartments was randomly chosen as the ALAN environment, or "illuminated compartment" (IC). The other compartment, the "dark compartment" (DC), remained unlit (i.e. 0 lux). At the opening between the compartments, on a perimeter of 5 cm^2, we measured 0.2 lux; this region was considered a "secure" area of the arena (Wolfe and Summerlin 1989, Kotler et al. 1991, Clarke 1983) because in the dark, hamsters are less visible to predators. At the beginning of each trial, the animal was removed from its cage and placed in the arena's entrance opening located midway between the LEDs (i.e. between the two compartments).

The hamsters were tested in two different conditions (Figure 1B). A light intensity of 4 or 40 lux was applied in the IC in both conditions, but the food source differed. In the high-quality food (HQF) condition, two live mealworms (1.2 cm, Truffaut) were placed below the functioning LED in the IC. This food is considered to be highly palatable for this species (Yves Handrich, personal communication). A low palatability food (two kibbles that they were accustomed to consume) was placed in the DC. In the low-quality food (LQF) condition, two kibbles were placed in each of the compartments. Eight trials of 15 min each at 4 or 40 lux (Figure 1B) were conducted for each individual in HQF and LQF conditions in randomly assigned order to limit any experimental design bias related to the location of the illuminated compartment (left or

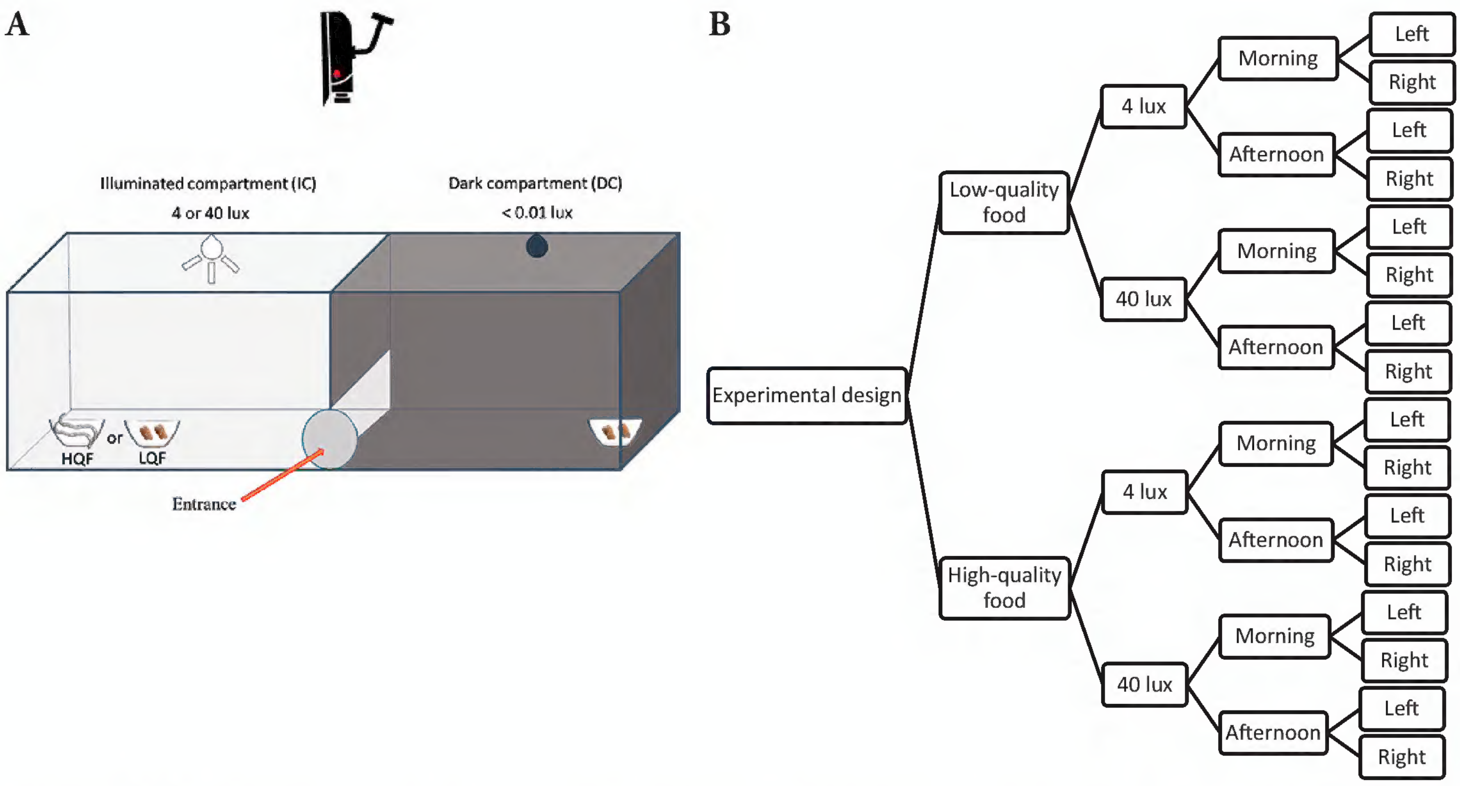

Figure 1. A Schematic representation of the test arena used for this experiment. Here, the left compartment is the Illuminated Compartment (IC). The source of light emitted was 4 or 40 lux. The right compartment is the Dark Compartment (DC) and contained an unlit amber LED. The two compartments are connected by an opening in the wall. Hamsters entered the arena through an opening (manually handled) located midway between the compartments. **B** Schematic representation of our experimental design. We performed 16 trials per individual hamster in a full-factorial design that included laterality (illuminated compartment on Left or Right of the test arena), time of the day (Morning or Afternoon), light intensity (4 lux or 40 lux) and food quality condition (HQF or LQF). We considered only the first trial for each light intensity and for each food quality condition. The four tests we are mentioning at the end of the paragraph were the ones used for the analysis, the others being conducted for checking the potential laterality and time of the day biases (but these trials were not used in the subsequent analyses).

right) and trial schedule (morning or afternoon). This trial duration was chosen to let individuals exploring all the arena and eating food without possibility of habituation. In addition, because we aimed to study the natural behaviour of hamsters encountering light in their environment, no acclimation period was considered.

Each 15-min trial was filmed using an infrared camera placed above the arena. Data were recorded by video monitoring. During the viewing, observers were blinded to the light intensity applied but not to the food quality condition because mealworms and kibbles are easy to distinguish. The time spent by individuals in IC and DC was calculated for each test. The proportion of time of foraging and grooming behaviour was recorded as well as the compartment in which the behaviour was performed was recorded. "Foraging" refers to any behaviour related to the active seeking or manipulation of food. Both mealworms and kibbles require several bites by hamsters in order to be entirely consumed. The term "grooming" refers to cleaning or scratching. Grooming behaviours were recorded because they could reflect individual stress level (Smolinsky et al. 2009). At the beginning of the testing period, none of the hamsters had previous experience of our experimental procedure.

Experiments were conducted between 9:00 am and 5:00 pm. For safety reasons, no testing was permitted by our administration during nights at the lab, so tests were conducted during the day. As this corresponds to the period when the hamsters would usually be asleep, we first ensured that individuals were sufficiently active. For 4 weeks, we filmed hamsters of a breeding room during the whole day and recorded their frequency of activities: mean hourly frequency of exploration was 2.45 ± 0.275; mean hourly frequency of foraging was 1.18 ± 0.202; mean hourly frequency of maintenance was 0.65 ± 0.085; with some individuals being quite active with 15 occurrences of exploration per hour, 12 occurrences of foraging per hour. Moreover, their frenzy observed in the presence of mealworms indicated they were sufficiently active during our trials. In addition, wild hamsters have been reported to display surface activity during the day in urban environments despite that they are nocturnal animals (Schmelzer and Millesi 2008).

Statistical analysis

All statistical analyses were performed using R.3.1.2 (R core Team 2015). To analyse the behavioural responses of hamsters exposed to ALAN, we ran generalised linear mixed-effect models (GLMM) using the R package 'lme4'. Individual identity was included as a random effect to consider pseudo-replication (i.e., the same hamster was used in 4 trials : 2 in the HQF (1 per light intensity - 4 lux and 40 lux) and 2 in the LQF condition (1 per light intensity - 4 lux and 40 lux), Hurlbert 1984) in each model. Best-fitting models were selected via an information-theoretic approach using the R package 'multcomp' and its 'dredge' function. This package uses the corrected Akaike Information Criterion (AICc), the delta AIC (ΔAIC) and the Akaike weight (Burnham and Anderson 2002). When ΔAIC > 2, the decision-making rule applied was to select the model with the lowest AIC value. When ΔAIC < 2, we chose the model with the lowest number of parameters by applying the principle of parsimony (Suppl. material 1: Tables S1, S2).

The first analysis concerned the time spent in each light condition. We ran two sets of models to explain our variable of interest by separating the two light intensity conditions (4 or 40 lux) in either HQF or LQF conditions. The response variable was expressed as the time spent by individuals in each compartment of the arena divided by the total proportion of time of a trial. We investigated the ability of hamsters to discriminate between our two compartments according to the light intensity thanks to paired Student's t-tests. We compared the time spent by each individual to chance level (50%: 450 out of 900 recorded seconds) using a binomial test.

The second analysis was the proportion of time spent engaged in behaviours (grooming or foraging). We ran two sets of models to explain our variables of interest in HQF and LQF conditions. The response variables were expressed as: (1) the time spent grooming in the illuminated compartment divided by the total time spent grooming, (2) the time spent foraging in the illuminated compartment of the arena divided by the total time spent foraging. The resulting proportions were considered a binomial distribution.

'Light intensity' (4 vs 40 lux) and 'sex' (male vs female) were fixed factors. Wald tests were performed to evaluate the effect of each fixed factor on these response variables.

The final analysis sought to determine the effect of food palatability on the time spent foraging in the illuminated compartment of the arena. We again considered the time spent foraging in the illuminated compartment divided by the total time spent foraging. The resulting proportion was considered a binomial distribution. 'Light intensity' (4 vs 40 lux), 'food quality' (HQF vs LQF) and 'sex' (male vs female) were fixed factors. Wald tests were again performed to compare the proportion of time of foraging in each condition and the effect of the light intensity on this variable.

To exclude a possible learning effect, only the first trial of each light intensity per food-quality condition for each hamster was considered in the analysis (N = 18 hamsters for each experimental condition). Analyses thus used data from four trials (LQF and HQF at 4 lux; LQF and HQF at 40 lux). We used Student's t-test to ensure that the time of day (morning or afternoon) and laterality (illuminated compartment on the left or the right of the arena) had no effect on the proportion of time of foraging and grooming and excluded these variables from our analysis (grooming proportion of time: Student's t-Test, $P_{\text{Time of day}} = 0.765$; $P_{\text{Laterality}} = 0.158$; Foraging proportion of time: Student's t-test, $P_{\text{Time of day}} = 0.114$; $P_{\text{Laterality}} = 0.275$). We did not observe an effect of the 'trial order', considered as a fixed variable, in any model, so we decided to exclude this variable from our analyses.

Results

Time spent in each light condition

In both HQF and LQF conditions, we found that individuals spent significantly more time in the DC than the IC when the IC was illuminated at 40 lux (Table 1). More precisely, we highlighted that individuals spent significantly less time in the IC compared to the chance level (Student's t-test, t = -2.62, *P*-value = 0.018; t = -2.14, *P*-value = 0.044 respectively for HQF and LQF). We found no significant difference in the proportion of time spent in the DC and the IC when the IC was illuminated at 4 lux (Table 1). More precisely, we observed that individuals spent equal time in the IC compared to 50% (Student's t-test, t = -0.350, *P*-value = 0.731; t = -1.50, *P*-value = 0.149 respectively for HQF and LQF).

Distribution of grooming and foraging behaviours

The best-fitting model for the proportion of time hamsters spent grooming in the HQF and LQF conditions included only the light intensity (Suppl. material 1: Table S1 and S2, respectively). More precisely, individuals groomed 4.34 and 4.08% longer in the IC when it was illuminated at 4 lux rather than 40 lux for the HQF and LQF treatments, respectively (Figure 2 and Table 2).

Table 1. Mean proportion (%, ± S.D.) of time spent in each compartment (Dark Compartment (DC) or Illuminated Compartment (IC)) of the arena according to the food quality condition (HQF or LQF) and to the light intensity in the IC (4 lux or 40 lux). Proportion of time spent in the DC was significantly different between our two Food quality conditions only when the IC was illuminated at 40 lux.

	Proportion of time spent in each compartment (%)			
Compartment	Dark compartment		Illuminated compartment	
	4 lux	40 lux	4 lux	40 lux
HQF condition	50.6 ± 7.5	55.9 ± 9.6	49.4 ± 7.5	44.1 ± 9.6
LQF condition	55.4 ± 13.0	59.2 ± 16.2	44.6 ± 13.0	40.8 ± 16.2

Table 2. Mean proportion of time (%, ± S.D.) spent grooming and foraging in both compartments of the arena (DC and IC) according to the Food quality condition (HQF or LQF) and to the light intensity in the Illuminated Compartment (IC, 4 lux or 40 lux). Proportion of grooming and foraging proportion of time in the IC was significantly different between our two experimental light intensities in both Food quality conditions.

	Proportion of time spent in each compartment (%)			
Behaviour – Testing condition	Dark compartment		Illuminated compartment	
	4 lux	40 lux	4 lux	40 lux
Grooming – HQF condition	60.1 ± 29.7	62.6 ± 37.1	39.9 ± 29.7	37.3 ± 37.1
Grooming – LQF condition	59.5 ± 29.7	66.4 ± 29.8	40.5 ± 29.7	33.6 ± 29.7
Foraging – HQF condition	43.4 ± 15.6	48.3 ± 19.6	56.7 ± 15.6	51.8 ± 19.6
Foraging – LQF condition	52.9 ± 19.2	45.5 ± 22.6	47.1 ± 19.2	54.5 ± 22.6

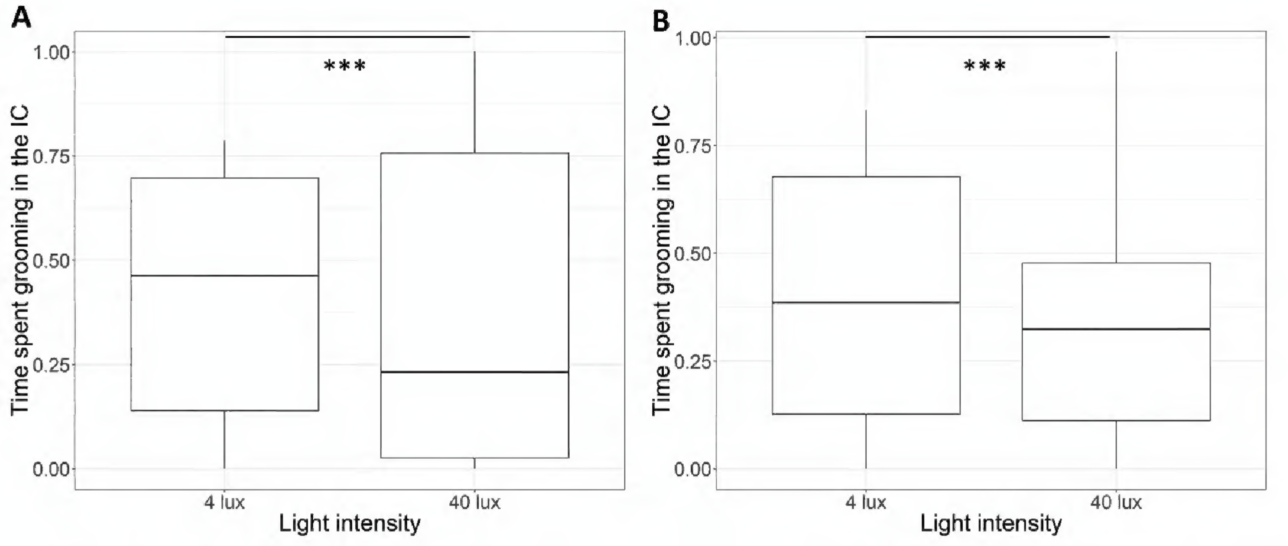

Figure 2. A In High-quality food condition, proportion of time spent grooming in the Illuminated Compartment (IC) according to the light intensity (4 lux or 40 lux) of this compartment. **B** In Low-quality food condition, proportion of time spent grooming in the Illuminated Compartment (IC) according to the light intensity (4 lux or 40 lux) of this compartment. The *** indicates the statistical difference at *P*-value < 0.001.

The best-fitting model for the proportion of time spent foraging in the HQF condition only included the light intensity (Suppl. material 1: Table S1). Individuals foraged 8.26% longer in the IC at 4 lux rather than at 40 lux (Figure 3 and Table 2). For the LQF condition, the best-fitting model also only included light intensity (Suppl. material 1: Table S2), but unlike in the HQF condition, individuals foraged only marginally (2.07%) longer in the IC at 4 lux than at 40 lux (Table 2).

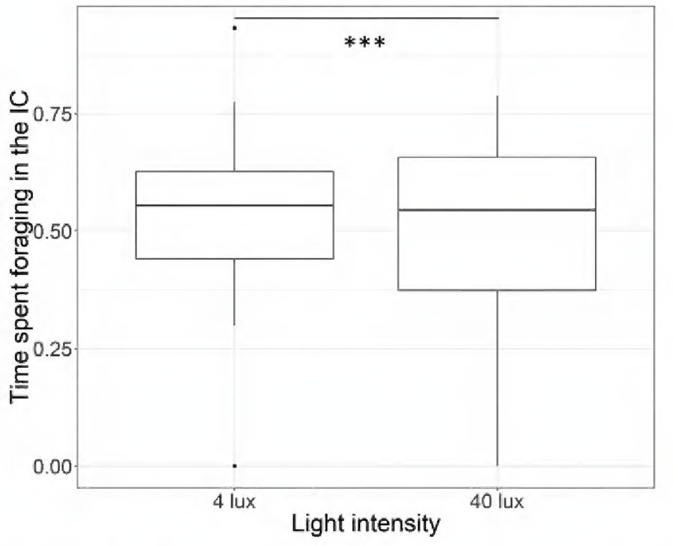

Figure 3. In the high-quality food (HQF) condition, the proportion of time hamsters spent foraging in the Illuminated Compartment (IC) according to the light intensity (4 lux or 40 lux) of this compartment. The *** indicates the statistical difference at *P*-value < 0.001.

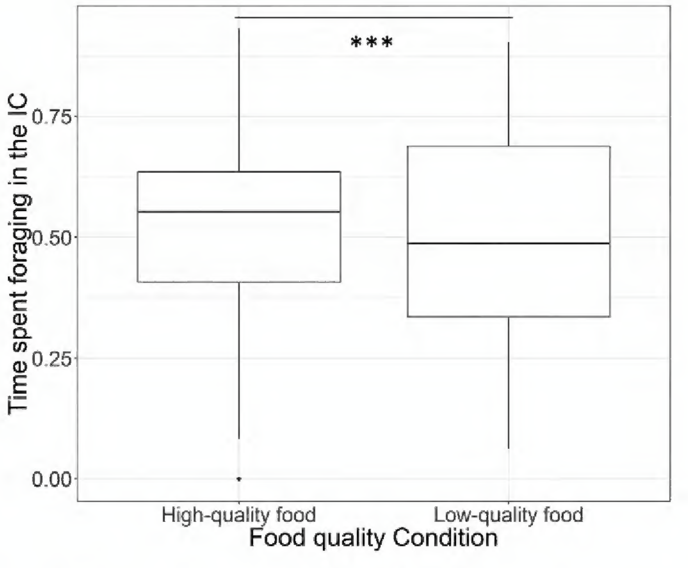

Figure 4. The effect of food quality on the proportion of time hamsters spent foraging in the Illuminated Compartment (IC) in the high-quality food (HQF) treatment (mealworms) and low-quality food (LQF) treatment (kibble) at 40 lux. The *** indicates the statistical difference at *P*-value < 0.001.

Effect of food palatability on the proportion of time of foraging in the IC

Considering the proportion of time of foraging in the IC, the best-fitting model solely included the food quality. Individuals foraged 12.5% longer in the IC when we placed a mealworm (HQF condition) rather than a kibble (LQF condition) below the light, whatever the light intensity (Wald's test, z = 6.78, *P*-value < 0.001; Figure 4 and Table 1). Then, hamsters increased their visibility to predators (i. e. frenzied and risky behaviours) in presence of highly attractive food.

Discussion

In this study, we experimentally tried to simulate the impact of public lighting, one of the main pressures encountered by wildlife in suburban habitats, which can entail serious consequences for the food-seeking behaviour of hamsters. Our strategy differs from other

conservation studies in Europe (Franceschini and Millesi 2003; Feoktistova et al. 2013; Čanády 2013; Surov et al. 2016) because the hamsters that are released are born in captivity and must adapt immediately to suburban conditions to survive. Our experiment may predict how hamsters could react in such an urban environment. First, we demonstrated that individuals generally avoided the illuminated area, especially in the case of high light intensity. In addition, our study also reveals that hamsters show more frenzied and risky behaviours (i.e., spend more time in illuminated conditions) in the presence of highly palatable food. Therefore, our results suggest that introducing hamsters in suburban areas could be a feasible project, but attention should be drawn to the light intensity applied and to the distance between high-quality food patches and streetlights.

In this study, we demonstrated that individuals generally avoided the illuminated compartment, particularly when grooming. We also found that avoidance of the illuminated area depended on the light intensity. Indeed, a low intensity of 4 lux (which reproduces the lighting in the peripheral zone of a streetlight) had less of an effect on hamster foraging than a lighting intensity of 40 lux (the equivalent of the lighting directly below a streetlight).

Our results suggest that hamsters living in suburban environments may generally avoid areas with street lighting. Our results confirm our predictions and corroborate the findings of previous studies that demonstrated rodents avoid illuminated areas (Farnworth et al. 2016, Bowers 1988). Such behaviour can be adaptive because it avoids detection by predators (Lockard and Owings 1974; Rosenzweig 1974; Kaufman and Kaufman 1982; Clarke 1983; Price et al. 1984; Wolfe and Summerlin 1989; Lima 1998; Jacob et al. 2017; Miller et al. 2017; review: Beier 2006), by associating light to predation risk (Orrock et al. 2004; Navarro-Castilla et al. 2018; for a review, see Lima and Dill 1990). Moreover, the avoidance of illuminated zones by rodents tends to reduce their foraging area and thus probably limits their food opportunities (Kotler 1984a, 1984b; Price et al. 1984; Bowers 1988; Vijayan et al. 2018). Indeed, O'Dowd and Hay (1980) indicated that diet composition of rodents seems to be negatively correlated with predation risk.

The hamster is a territorial and solitary species, so the probable restriction of resources due to ALAN in suburban areas might lead this animal to increase 1) the time budget allocated to foraging in its home range, and/or 2) the distances it travels – i.e. beyond the borders of its own territory – in order to complete potential food stock, both possibly entailing more frequent intraspecific conflicts. This would increase predation risk and reduce foraging efficiency (i.e. energy intake/energy used for foraging). Consequently, the highly developed lighting system in large suburban areas of Alsace is expected to have a negative impact on hamsters. Limiting the number of lamp posts, applying moderate levels of lighting or switching off streetlights during the hamsters' period of activity might be a solution to limit the adverse effects of ALAN on the behaviour, body condition and survival of hamsters released on the outskirts of suburban areas. The application of these measures would create favourable conditions for the release of hamsters raised in captivity. More generally, such conditions may be favourable to any wildlife species.

Our study also reveals that although hamsters are able to discriminate between both compartments, they show frenzied and risky behaviours when confronted with highly

attractive food. If we extrapolate this lab situation to real suburban conditions, this behaviour could render hamsters more vulnerable to predation. Indeed, instead of hoarding food from the illuminated compartment to the dark compartment as they do classically by going back to their burrow in order to consume the food (Ziomek et al. 2009), in our study, hamsters consumed the mealworm immediately in the IC. The hamsters' natural aversion to light appeared to be modified in response to the high palatability of food, which has been demonstrated in other species (Nonacs and Dill 1990a, b; Underwood et al. 2017). In a real-life context, such behaviour would render them easily detectable by a predator. As a consequence, the success of releasing hamsters in suburban areas must take into consideration the behaviour of hamsters in response to highly palatable food. Our work suggests that highly palatable food plants should be planted at a sufficient distance from lighting equipment to decrease hamsters' vulnerability to predators.

This study is part of a larger research programme that will help providing advice for territorial planning in order to successfully reintroduce this species in suburban areas, and will thus contribute to the restoration of viable populations in France. We believe that testing how captive-bred animals might cope with challenging environments in controlled conditions is a necessary step before releasing animals into the wild for conservation purposes. Another recommended step (which is on the agenda of the French National Plan of Actions, Virion 2018) is to habituate captive hamsters to wild conditions (in outdoor enclosures during day and night) before releasing them in fields to increase their survival.

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Author contribution

SMD, LG, CW and OP conceptualized this experiment. SMD achieved formal analysis and wrote the original draft. LG, CW and OP revised the manuscript.

asd

Authors	Contribution	ACI
SMD	0.40	2.000
LG	0.20	0.750
CW	0.10	0.333
OP	0.30	1.286

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Supplementary material 1

Supplementary tables

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Data type: statistical data

Explanation note: **Table S1:** Influence of light pollution on the grooming and foraging durations in High-quality food condition. **Table S2:** Influence of light pollution on the grooming and foraging durations in low-quality food (LQF) condition.

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